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Consumer and Warner-Bratzler Shear Evaluations of Steaks from Blade Tenderized, Aged, or Frozen Sirloin Subprimals

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Abstract: Paired USDA Choice top sirloin butts (n = 60) were divided equally across 3 trials: 1) blade tenderized (BT) versus non-blade tenderized (NBT), 2) refrigerated versus frozen aging/storage, and 3) 14-d versus 35-d refrigerated aging. Steaks from subprimals were evaluated using Warner-Bratzler Shear (WBS) force testing and consumer sensory evaluation. Consumers found BT steaks to be more tender and palatable compared to NBT steaks ($P < 0.05$), even though WBS values did not differ. Steaks from refrigerated versus frozen and 14- versus 35-d age treatments did not differ ($P > 0.05$) in consumer sensory ratings or WBS values. When compared to refrigerated, frozen storage of product did not affect consumer sensory ratings. Lack of differences between 14- and 35-d aging treatments indicated that the top sirloin butt did not require extended-aging periods to increase tenderness. Blade tenderization remains important for the top sirloin; however, purveyors may have options in postmortem aging and frozen storage of product without sacrificing quality.

Keywords: aging, beef, blade tenderization, freezing, sirloin
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Introduction

The beef top sirloin steak is an important foodservice cut due to its demand by cost-concerned consumers. Yet, in comparison to steaks from the rib and loin, the top sirloin often fails in delivering consistent and satisfactory eating experiences to foodservice clientele, which is an important fact to consider since consumers view tenderness as the most important organoleptic characteristic of meat (Koohmaraie, 1994). Morgan et al. (1991) identified top sirloin steaks as the toughest cut with the lowest sensory ratings compared to other steaks from the loin during the 1990 National Beef Tenderness Survey (NBTS), with over 50% of the panelists' sensory scores ranking the retail cut below the "moderately tender" designation. In the 1998 NBTS, average Warner Bratzler Shear (WBS) force values improved for the top sirloin, yet these were still the greatest values for cuts from the rib and loin (Brooks et al., 2000). This trend continued into the 2010 NBTS (Guelker et al., 2013), where top sirloins only ranked numerically above samples from the top round and bottom round in sensory retail tenderness evaluations. Furthermore, top sirloins maintained the greatest percentage of steaks ranking "intermediate" and "tough" in the food service category when steaks were stratified by WBS force tenderness. Guelker et al. (2013) reported in the 2010 NBTS that the WBS force values were numerically similar to those in the 2006 survey, and the industry could be experiencing a "possible plateau of beef tenderness." Martinez et al. (2017) refuted this theory in the 2015/2016 NBTS, where the mean WBS force value of the top sirloin decreased from the 2010 NBTS.

To combat shortcomings inherent to the sirloin, a variety of processes have traditionally been implemented to increase consumer acceptability. The benefits of using blade tenderization to enhance tenderness are known (George-Evins et al., 2004, King et al., 2009, Savell et al., 1977), yet other aging options are available that may minimize the food safety risks associated with blade tenderization. Wheeler et al. (1990) stated that utilization of frozen steaks rather than chilled steaks can offer the advantages of increased storage time, greater flexibility in inventory, and greater product control. Furthermore, Grayson et al. (2014) reported that freezing and thawing of meat, or freezing and thawing combined with aging, reduced slice shear values and may be a method to improve meat tenderness. Additionally, it is known that postmortem aging of beef increases tenderness due to endogenous enzymes in the muscle causing loss of structure and strength of the myofibril (Smith et al., 1978). However, Harris et al. (1992) reported that the extensive length of time required for tenderness changes in sirloin steaks could lead to undesirable effects, such as off-flavor and soft texture.

The objectives of this study were: 1) to determine if consumer satisfaction improves by blade tenderizing today's more inherently tender beef, 2) to evaluate the use of freezing of top sirloin butts during the subprimal storage period to see if it will enhance tenderness of steaks, and 3) to assess whether a short aging period for top sirloin butts would produce steaks of the same quality when compared to those from top sirloin butts aged for the traditional extended periods.

Materials and Methods

Consumer panel procedures were approved by the Texas A&M Institutional Review Board for Use of Humans in Research (IRB2016–0227M).

Product collection

Paired USDA Choice beef loin, top sirloin butt, semi center-cut, boneless subprimals (n = 60 total pieces), similar to USDA (2014) Institutional Meat Purchase Specifications (IMPS) 184A (primarily consisting of the *M. gluteus medius*, with the *M. biceps femoris*, the *M. gluteus profundus* and *M. gluteus accessorius* removed), were collected from a major beef supplier. Subprimals were obtained from carcasses selected using the following criteria: 1) under 30 mo of age, 2) no dairy or *Bos indicus* influence, 3) overall acceptable quality of exposed *M. longissimus thoracis* area at the 12th rib (no blood splash, discoloration, or exudation), and 4) carcass weights ranging from 272 to 408 kg (mean = 358.7 kg).

After fabrication, subprimals were labeled, vacuum packaged individually, boxed, and shipped under refrigeration to a collaborating beef purveyor. Paired subprimals were divided equally among 3 trials: 1) blade tenderized (BT) vs. non-blade tenderized (NBT) treatments, 2) refrigeration vs. frozen aging, and 3) 14-d vs. 35-d refrigerated aging. For all trials, aging periods began the day of subprimal fabrication, which occurred 2 d postmortem.

Trial 1: blade tenderized versus non-blade tenderized

Ten paired top sirloin butts (n = 20 total pieces) were used. All products were aged under refrigeration (~ –1°C) for 28 d. All top sirloin butts from the left side of the carcasses were assigned to the BT treatment. Top sirloin butts, dorsal side facing up, were run once through a commercial blade tenderizer (Ross TC700W, Midland, VA). Top sirloin butts from the right sides received no treatment (non-blade tenderized; NBT) and served as the control.

Trial 2: refrigerated versus frozen aging/storage

Ten paired top sirloin butts (n = 20 total pieces) were used. All products were aged initially under refrigeration (~ –1°C) for 14 d. From each pair, the left top sirloin butt was frozen (~ –20°C) for 14 d, then returned to refrigeration (~ –1°C) for 7 d, achieving an aging/storage period of 35 d. Right top sirloin butts remained under refrigeration for the entire 35-d aging/storage period, serving as the control.

Trial 3: 14-d versus 35-d aging

Ten paired top sirloin butts (n = 20 total pieces) were used. Left top sirloin butts of each pair were aged under refrigeration (~ –1°C) for 14 d before cutting into steaks. Right top sirloin butts from the pair were aged under refrigeration (~ –1°C) for 35 d before cutting into steaks.

Subprimal fabrication

After treatment application, a Grasselli (NSL 800, Albinea, Italy) slicer was used to generate 5 2.5-cm-thick portions from each subprimal by cutting dorsal to ventral (approximately perpendicular to the muscle fibers) with the third portion being from the middle of the subprimal. Portions were identified as 1, 2, 3, 4, and 5, cranial to caudal. Only portions 2 and 3 were used in this study. These portions were cut into thirds to produce 3 steaks (2.5-cm thick from the initial slicing), which were identified as Steaks A, B, and C from portion 2, and Steaks D, E, and F from portion 3. These steaks were hand-trimmed to produce steaks that weighed approximately 170 g. To reduce inherent location effects, steaks from the same anatomical location from each these portions were used for sensory and for WBS force evaluations, respectively. Steak A was used for Warner-Bratzler Shear (WBS) force, Steaks B, C, D, and E were used for consumer sensory panels, and Steak F was held in reserve.

Packaging

Steaks were labeled and vacuum packaged individually with a rollstock machine (Multivac R150; Kansas City, MO) using Sealed Air, Food Care Division (Charlotte, NC) Item No. T7230B 3.0 mil top web with an Oxygen Transmission Rate (OTR) 4 [cc/m^2 per d at 23°C, 0% R.H] and Item No. T7045B 4.5 mil bottom web with an OTR of 3 [cc/m^2 per d t 23°C, 0% R.H]. Steaks then were boxed and placed into plastic insulated containers with refrigerated materials and transported to Texas A&M University (College Station, Texas). Upon arrival, steaks were stored under refrigerated conditions (~ 0°C) until subsequent analyses; steaks for trial 3 were flash frozen (–40°C) after packaging, then stored frozen (~ –23°C) and later thawed for testing.

Cooking of steaks

Steaks for consumer sensory analysis and WBS force were cooked in the same manner. For Trials 1 and 2, cooking was completed within 3 d of the steaks arriving in College Station. For Trial 3, frozen steaks were thawed under refrigerated conditions (~ 0°C) for 48 h before cooking. All steaks were cooked on a Star International commercial flat-top grill (Max Model 536TGF, St. Louis, MO). The grill was preheated to 176°C ± 2°C, with internal steak temperatures monitored using thermocouple readers (Model HH506A; Omega Engineering, Stanford, CT) and 0.02 cm diameter copper-constantan Type-T thermocouple wire (Omega Engineering) inserted into the geometric center of each steak. Steaks were cooked to 35°C, flipped, and cooked to a final endpoint temperature of 70°C. Raw out of package weight, initial internal temperature, grill temperature, final internal temperature, cook time, final cook weight, and cook loss were all collected on each steak (Tables 1, 2, and 3). Steaks assigned to consumer panels were kept warm by placing them in an Alto-Shaam oven set at 60°C (Model 100-TH, Alto-Shaam Inc., Menomnee Falls, WI) for no more than 20 min. Steaks for WBS force were placed on plastic trays in a manner to avoid any overlapping, covered with plastic wrap, and stored in a cooler (2 to 4°C) for 12 to 18 h before analysis.

Table 1. Paired t-tests for weights, steak temperatures, cook loss, grill temperature, and cook duration of sensory and Warner-Bratzler shear force steaks from subprimals that were blade tenderized versus not blade tenderized

Treatment[1]	n[2]	Raw weight, g	Raw internal temperature, °C	Cooked weight, g	Cooked internal temperature, °C	Cook loss, %	Grill surface temperature, °C	Cook duration, min
BT	10	177.7	11.2	133.6	70.1	24.9	177.1	18.9
NBT	10	171.2	10.9	129.8	70.1	24.1	177.1	18.9
SE		1.43	0.08	1.76	0.07	0.59	0.35	0.75
Prob > t		0.9993	0.9980	0.0304	0.3860	0.8849	0.5393	0.5923

[1]Treatment: BT = top sirloin butts were run once through a blade tenderizer before cutting into steaks; NBT = top sirloin butts were not blade tenderized before cutting into steaks.

[2]Number of subprimals evaluated.

Table 2. Paired t-tests for weights, steak temperatures, cook loss, grill temperature, and cook duration of sensory and Warner-Bratzler shear force steaks from subprimals that were refrigerated versus frozen during aging

Treatment[1]	n[2]	Raw weight, g	Raw internal temperature, °C	Cooked weight, g	Cooked internal temperature, °C	Cook loss, %	Grill surface temperature, °C	Cook duration, min
Refrigerated	10	179.9	12.0	137.0	70.2	23.8	177.2	20.3
Frozen	10	170.0	12.4	128.7	70.0	24.4	176.8	17.6
SE		3.14	0.16	2.73	0.08	0.59	0.33	0.60
Prob > t		0.0059	0.9678	0.0073	0.0436	0.8081	0.8525	0.9993

[1]Treatment: Refrigerated = top sirloin butts were aged under refrigeration for 35 d before cutting into steaks; Frozen = top sirloin butts were aged under refrigeration for 14 d, frozen for 14 d, and then placed back in refrigeration for 7 d before cutting into steaks.

[2]Number of subprimals evaluated.

Table 3. Paired t-tests for weights, steak temperatures, cook loss, grill temperature, and cook duration of sensory and Warner-Bratzler shear force steaks from subprimals that were aged for 14- versus 35 d

Treatment[1]	n[2]	Raw weight, g	Raw internal temperature, °C	Cooked weight, g	Cooked internal temperature, °C	Cook loss, %	Grill surface temperature, °C	Cook duration, min
14 d	10	169.6	13.6	128.6	70.1	24.1	176.5	16.9
35 d	10	166.0	13.2	124.9	70.1	24.8	176.6	17.1
SE		4.60	0.35	3.40	0.04	0.92	0.24	0.66
Prob > t		0.7782	0.8637	0.8542	0.3484	0.2242	0.2700	0.2901

[1]Treatment: 14 d = top sirloin butts were aged for 14 d under refrigeration before cutting into steaks; 35 d = top sirloin butts were aged for 35 d under refrigeration before cutting into steaks.

[2]Number of subprimals evaluated.

Consumer sensory analysis

Consumer panelists (n = 80 per trial) were recruited from the Bryan/College Station area using an existing consumer database. Upon arrival at the sensory facility, panelists completed a demographic survey (Tables 4 and 5) and were provided with a brief orientation of the procedure for sample evaluation. Samples were prepared by cutting cooked steaks into fourths. Each one-fourth of a steak was served on a plastic plate along with a metal steak knife and a plastic fork to simulate a typical eating experience for the panelists. For each of the 3 trials, consumer sensory sessions were conducted over 2 d (2 sessions per d). Per session, twenty panelists were divided among 5 groups. Within each group of 4 panelists, a single panelist evaluated 2-matched pairs (4 samples), which resulted in each group evaluating 4 steaks for a total of 20 steaks per session and 80 steaks per trial. All samples were served in a double-blind and random order assigned by a random number generator (Microsoft Excel; Microsoft Corp., Redmond WA) and checked for duplicates.

Panelists were provided with Nabisco Unsalted Tops Premium Saltine Crackers (Kraft Foods Global, Inc., East Hanover, NJ) and double-distilled, deionized water to use as palate cleansers between each sample. Serving order was randomized for each group to eliminate first-order bias. Samples were served through individual breadbox-style sensory booths equipped with red theater lighting to prevent panelist bias for degree of doneness. Panelists evaluated samples using 9-point scales (1 = dislike extremely; 9 = like extremely) for overall liking, flavor liking, tenderness liking, and juiciness liking.

Table 4. Demographic summary of consumer panelists (n = 240)

Item	n[1]	%
Gender		
Male	131	55
Female	109	45
Age		
20 yr or younger	15	6
21 - 25 yr	75	31
26 - 35 yr	60	25
36 - 45 yr	22	9
46 - 55 yr	27	11
56 - 65 yr	24	10
66 yr and older	17	7
Working status		
Not employed	20	8
Part-time	39	15
Full-time	103	40
Student	93	37
Annual household income		
$100,000 or more	56	23
$75,000 - 99,999	30	13
$50,000 - 74,999	34	14
$25,001 - 49,999	39	16
Below $25,000	81	34
Dietary restrictions		
No	226	94
Yes	14	6
Self/Immediate family works for a food company		
No	237	99
Yes	3	1
Ethnic background		
White	198	83
Hispanic	20	8
Asian or Pacific Islander	9	4
Black	8	3
Other	4	2

[1]No. of responses.

Warner-Bratzler Shear Force analysis

Following the cooler storage period, steaks were allowed to equilibrate to room temperature before being trimmed of visible connective tissue to expose muscle fiber orientation. Using a hand-held coring device, six 1.3-cm cores were removed from each *M. gluteus medius* (GM) making sure to sample the entire steak. Connective tissue and excess fat were avoided when coring as much as possible. Cores were removed

Table 5. Consumer panelists' consumption patterns (n = 240)

Item	n[1]	%
Meat consumption		
Yes	240	100
Type of meat consumed		
Beef	240	100
Chicken	239	99
Fish	209	87
Pork	231	96
Frequency of beef consumption		
Daily	19	8
5 or more times per wk	50	21
3 or more times per wk	114	48
Once per wk/weekly	49	20
Once every 2 weeks	6	2
Less than once every 2 wk	2	1
Frequency of beef consumed at home per wk		
0	12	5
1	55	23
2	80	34
3	56	24
4	24	10
5	3	1
5+	8	3
Frequency of beef consumed at restaurant per wk		
0	9	4
1	102	43
2	70	29
3	31	13
4	15	6
5	5	2
5+	7	3
Preferred degree of doneness		
Rare	8	3
Medium rare	79	32
Medium	5	2
Medium well	106	43
Well done	51	20
Type of beef purchased		
Aged	26	9
Grass-fed	29	10
Organic	18	6
Traditional	213	75

[1]No. of responses.

parallel to the muscle fibers and sheared once, perpendicular to the muscle fibers, on a United Testing machine (United SSTM-500, Huntington Beach, CA) at a cross head speed of 200 mm/min using a 10-kg load cell, and a 1.02 cm thick V-shape blade with a 60°angle and a half-round peak. The peak force (kg) needed to shear each core was recorded, converted to Newtons (N), and the mean peak shear force of the cores was used for statistical analysis. The equipment was calibrated before the start of data collection, and calibration was checked after shearing every 60 cores.

Statistical analysis

Microsoft Excel (Microsoft Corporation, Redmond, WA) was used to calculate frequencies for consumer panelists' demographics. Trial data were analyzed separately with paired t tests, using the matched pairs function of JMP (Version 12, SAS Inst. Inc., Cary, NC), at an α of 5%.

Results and Discussion

Blade tenderized versus non-blade tenderized

Paired t tests for sensory panel ratings and WBS force values for steaks from BT and NBT are reported in Table 6. Steaks that were BT had higher ($P < 0.05$) overall liking, flavor liking, and tenderness liking ratings than did steaks from the NBT treatment. There was no difference in the comparison of the 2 treatments for juiciness liking. Interestingly, although tenderness liking differences occurred, there were no differences ($P > 0.05$) between treatments for WBS force values. George-Evins et al. (2004) found overall tenderness improvements in top sirloin steaks from subprimals that had been blade tenderized at least once, similar to Savell et al. (1977) and King et al. (2009) who found decreases in WBS force and slice shear force values, respectively, in the GM due to blade tenderization. It was expected that blade tenderization would result in improved WBS force values, but it was not expected that consumer sensory panelists would be able to differentiate between treatments. However, we found the opposite.

Connective tissue is a dominant factor affecting meat tenderness, with Harris et al. (1992) reporting that tenderness variations in top sirloin steaks were mainly due to amount and solubility of collagen when compared to the top loin steak. Although connective tissue weakens as cooking temperature increases past 50°C due to more extensive denaturation (Lewis and Purslow, 1989), other authors discount the prioritization of connective tissue as the main driver of meat tenderness. Harris et al. (1992) and Torrescano et al. (2003) found a stronger correlation between WBS force with total collagen and insoluble collagen content over that of sarcomere length. Conversely, Purslow (2005) considered connective tissue more of a "background contributor" to meat tenderness due to the dif-

Table 6. Paired t-tests for sensory panel ratings and Warner-Bratzler shear force values for steaks from subprimals that were blade tenderized versus not blade tenderized

		Sensory panel ratings[3]				Warner-Bratzler shear force, N
Treatment[1]	n[2]	Overall like/dislike	Tenderness like/dislike	Flavor like/dislike	Juiciness like/dislike	
BT	10	6.7	6.7	6.7	6.4	26.4
NBT	10	6.3	6.0	6.5	6.1	28.2
SE		0.14	0.15	0.08	0.20	2.29
Prob > t		0.0293	0.0011	0.0198	0.1138	0.4395

[1]Treatment: BT = top sirloin butts were run once through a blade tenderizer before cutting into steaks; NBT = top sirloin butts were not blade tenderized before cutting into steaks.

[2]Number of subprimals per treatment.

[3]Sensory panel ratings: 9 = like extremely; 1 = dislike extremely.

ficulty in manipulating this factor. Yet, it has also been reported that muscle fiber properties may have greater influence over WBS force and consumer evaluations in perception of tenderness (Cross et al., 1973).

Combined with the location on the carcass causing a relative lack of stretching, fiber type helps to explain why the top sirloin traditionally records shorter sarcomere lengths compared to other cuts in the loin (Herring et al., 1965, Rhee et al., 2004). The collaborating factors of shorter sarcomeres and higher collagen correlate highly to muscle tenderness (Wheeler et al., 2002), and explain why disruption of both contractile and connective tissues through blade tenderization increase tenderness in the top sirloin (King et al., 2009, Savell et al., 1977).

Refrigerated versus frozen aging/storage

There were no differences in sensory panel ratings ($P > 0.05$) or WBS force values between treatments (refrigerated versus frozen; Table 7). The average WBS force values for steaks from both refrigerated and frozen treatments were within the "very tender" category (Belew et al., 2003).

The use of freezing as a method to enhance tenderness and extend shelf life has long been a topic of interest in industry. It is known that freezing meat is advantageous in that it preserves product longer than fresh storage; however, freezing also increases drip loss and causes ultrastructural changes in the muscle fiber (Lagerstedt et al., 2008, Wheeler et al., 1990). These changes are caused by the freezing and thawing process, which alters the state of water within the muscle by creating compartments of ice between the muscle fibers (Leygonie et al., 2012). These compartments of water can form large, extracellular ice crystals, which can damage the structure of the myofibril and lead to fragmentation, resulting in tenderization (Leygonie et al., 2012).

Research conducted observing the effects of freezing on a variety of muscles on meat quality has produced varying results in relation to tenderness (Grayson et al., 2014, Hergenreder et al., 2013, Hiner et al., 1945, Howard et al., 2013, Shanks et al., 2002, Wheeler et al., 1990). Works by Grayson et al. (2014), Hiner et al. (1945), and Shanks et al. (2002) support the theory that freezing and thawing of meat improves tenderness, whereas reports by Howard et al. (2013) and Wheeler et al. (1990) conversely do not. Shanks et al. (2002) found that across 9 postmortem aging periods, WBS force values were lower in frozen beef *M. longissimus* steaks than fresh steaks. Interestingly,

Table 7. Paired t-tests for sensory panel ratings and Warner-Bratzler shear force values for steaks from subprimals that were refrigerated versus frozen during aging

		Sensory panel ratings[3]				Warner-Bratzler shear force, N
Treatment[1]	n[2]	Overall like/dislike	Tenderness like/dislike	Flavor like/dislike	Juiciness like/dislike	
Refrigerated	10	6.3	6.0	6.4	5.8	26.7
Frozen	10	6.1	5.8	6.2	6.1	30.7
SE		0.14	0.21	0.11	0.26	1.97
Prob > t		0.0946	0.3017	0.1005	0.2870	0.0733

[1]Treatment: Refrigerated = top sirloin butts were aged under refrigeration for 35 d before cutting into steaks; Frozen = top sirloin butts were aged under refrigeration for 14 d, frozen for 14 d, and then placed back in refrigeration for 7 d before cutting into steaks.

[2] Number of subprimals per treatment.

[3]Sensory panel ratings: 9 = like extremely; 1 = dislike extremely.

Hergenreder et al. (2013) reported that across 3 different frozen treatments, WBS force values for sirloins were not different. The differing outcomes of these studies could be due to various factors including grade, aging conditions, the unique physiology of the muscle, and aspects of experimental design.

When considering the impact of freezing on consumer perception, Grayson et al. (2014) found that when top loin and eye of round steaks were aged for some time, frozen, and then thawed, there were enough improvements in tenderness to warrant concern that steaks destined for research sensory analysis could be impacted by the freezing process. It is important to note that this research was done on steaks, and not individual subprimals like the current study. Lagerstedt et al. (2008) found that sensory attributes of beef *M. longissimus* samples were altered by freezing, reporting lower shear force values for frozen versus chilled samples at 14 d of aging. Conversely, this study showed no differences in consumer perception of chilled meat compared to that which had been frozen, while trained sensory panel results showed the opposite (Lagerstedt et al., 2008).

In the current study, it was not known if freezing and thawing of the top sirloin subprimal would provide the same tenderness benefits as those seen with individual steaks (Grayson et al., 2014). We found that freezing and thawing of subprimals did not impact palatability ratings or WBS force values when compared to subprimals that were only refrigerated during storage. This highlights the opportunity for increased flexibility in industry for inventory control purposes because freezing and thawing subprimals did not negatively impact consumer acceptability or shear force values.

14-d versus 35-d aging

Across the industry, use of extended aging periods has been historically used as a method to enhance tenderness by altering the myofibrillar structure postmortem. Yet, previous research has shown that combining practices could potentially be more beneficial than relying on aging alone. This is likely due to the further alteration of tenderness factors such as connective tissue and sarcomere length through additional practices such as blade tenderization or carcass suspension. Savell et al. (1982) reported that the most effective way to decrease WBS force values was not to rely on aging alone, but to combine blade tenderization, electrical stimulation, and an 18-d aging period. The current study aimed to determine if aging alone could alter perception of palatability and tenderness in top sirloin steaks. Aging product for an additional 21 d (14 versus 35 d) did not ($P > 0.05$) increase consumer sensory panel ratings or result in a reduction ($P = 0.1215$) of WBS force values (Table 8). The average WBS force values for steaks from both treatments were within the "very tender" category (Belew et al., 2003).

Extended aging periods work to disrupt the integrity of the myofibrils through proteolysis (Koohmaraie et al., 1991). As these enzymatic processes occur over time, total time subprimals are aged can have an effect on meat tenderness. The 2015/2016 NBTS reported that subprimal aging times at retail averaged 25.9 d, ranging from 6 to 102 d (Martinez et al., 2017). This is in contrast to the previous NBTS studies, which reported shorter post-fabrication aging periods at the retail level. Guelker et al. (2013) reported an average retail aging period of 20.5 d, compared to Voges et al. (2007) and Brooks et al. (2000) who reported averages of 22.6 and 19.0 d, respectively. As industry aging time increases, this may contribute to enhanced tenderness of sirloins due to the additional time allowed for proteolysis to occur.

Harris et al. (1992) found that although there were overall improvements in panel tenderness ratings after aging top sirloins for 28 d, WBS force values showed no significant decreases up to 35 d of aging. The lack of

Table 8. Paired t-tests for sensory panel ratings and Warner-Bratzler shear force values for steaks from subprimals that were aged for 14 versus 35 d

		Sensory panel ratings[3]				Warner-Bratzler shear force, N
Treatment[1]	n[2]	Overall like/dislike	Tenderness like/dislike	Flavor like/dislike	Juiciness like/dislike	
14 d	10	6.0	5.6	6.3	5.6	30.7
35 d	10	6.1	6.0	6.1	5.9	27.5
SE		0.25	0.29	0.20	0.28	1.81
Prob > t		0.6321	0.1868	0.3795	0.2948	0.1215

[1]Treatment: 14 d = top sirloin butts were aged for 14 d under refrigeration before cutting into steaks; 35 d = top sirloin butts were aged for 35 d under refrigeration before cutting into steaks.

[2]Number of subprimals per treatment.

[3]Sensory panel ratings: 9 = like extremely; 1 = dislike extremely.

improvement in tenderness of top sirloins solely receiving an aging treatment has been attributed to the higher content of connective tissue in the sirloin that does not degrade during aging (Harris et al., 1992). Colle et al. (2015) agreed, reporting that there were no differences in soluble or insoluble collagen in the sirloin during aging, and attributed any likely change in tenderness to proteolytic systems. Colle et al. (2015) reported that the GM be aged for at least 42 d to optimize consumer perception of tenderness, having found no significant tenderness increase until this point.

It is clear from the present study that up to 35 d of aging does not result in improved palatability or WBS force values of the top sirloin when compared to those subprimals aged for 14 d. Because the top sirloin does not respond to aging like other rib and loin cuts, our knowledge of the aging practices used by most purveyors is that they employ extended-aging times as a way to ensure tenderness. Based on these findings, there is no benefit to extending the aging periods for the top sirloin, thus providing the industry with potential evidence to decrease storage times and expedite shipping to increase product availability.

Conclusion

Today's inherently tender beef has been a benefit to the industry, and because of this, traditional practices of postmortem aging, blade tenderization, and freezing needed to be revisited to ensure that their benefits are still worthwhile. This study showed that longer aging periods (e.g., up to 35 d) are not needed for top sirloin butts, as shorter aging periods (e.g., 14 d) produced steaks of comparable sensory and WBS force characteristics. These findings allow purveyors flexibility in utilizing shorter product storage periods without sacrificing meat tenderness or quality.

Our work showed no objective or subjective differences in comparing beef aged under refrigerated versus frozen conditions. Freezing and thawing of top sirloin butts compared to only aging them under refrigeration achieved similar and interchangeable palatability characteristics between steaks. These findings offer purveyors, retail, and foodservice establishments options in how top sirloin butts are handled before cutting into steaks, alleviating the concern of detrimental consumer perceptions due to freezing.

Finally, blade tenderization did improve sensory panel ratings for overall and tenderness liking compared to the non-blade tenderized controls. Although WBS force values were similar between treatments, improvements in sensory panel ratings with blade tenderization show that this common method of enhancing tenderness is still beneficial for the top sirloin steak.

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